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A stable, high-power broadband Pr3+-doped fiber superfluorescence source

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mode (NF and FF are identical) is shown in Fig. 3a. For larger arrays, the required pulse duration for generating the pure Hermite-Gaussian modes was even longer. The Hermite-Gaussian mode (NF and FF) of an 11×11 laser array, excited by a current pulse ~1 microsec. long, is shown in Fig. 3b.

The nonlinear evolution of these array modes and the analysis of time scales required for achieving coherency over large arrays as well as the dynamic control over modal pattern by pulse width modulation are discussed.

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QMG2 1430

Laser emission in $Al_xGa_{1-x}As$ with indirect band gap

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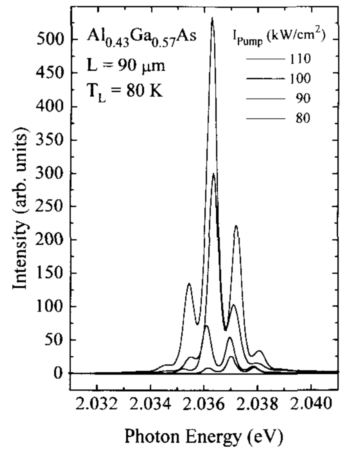
As a promising possibility to realize visible lasers compatible with GaAs we report for the first time laser emission up to 300 K from $Al_xGa_{1-x}As$ with indirect band gap close to the direct-to-indirect crossover.

Although $Al_xGa_{1-x}As$ is a material with an indirect fundamental band gap at a composition of $x_c \geq 0.43$ for 5 K,[1] the transition probability for indirect recombination is strongly enhanced because of effective alloy-disorder-induced intervalley scattering[2] for small energy separation of the X-and Γ-conduction band minima. The resulting emission wavelength lies in the red spectral range (635 nm at 300 K).[3]

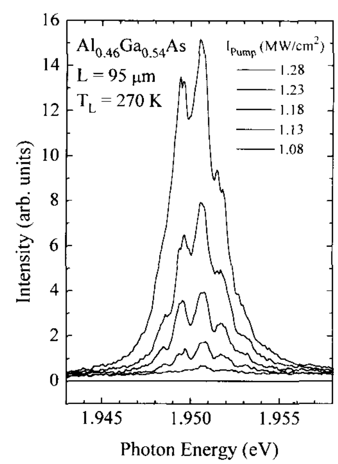
We performed photoluminescence measurements using stripe-like nanosecond excitation of samples, which are cleaved into resonators of around 100 μm width. The samples consist of 0.5-μm thick active layers of $Al_xGa_{1-x}As$ between $Al_{0.7}Ga_{0.3}As$ cladding layers. Laser activity is proved unambiguously by both criteria: threshold-like behavior of the onset of stimulated emission and occurrence of resonator-mode structures in the emission spectra.

Very sharp laser modes are demonstrated in Fig. 1 for a sample with a composition of $x = 0.43$ at relatively low lattice temperature (80 K). Figure 2 shows laser emission at 270 K for a sample with composition of $x = 0.46$. This composition is more suitable for indirect-gap laser emission because of the temperature shift of the direct-to-indirect crossover to $x_c \approx 0.45$ at 300 K. The product of mode separation and cavity length is a constant value, so the mode structure can be assigned unambiguously to the resonator. In comparison to emission from uncleaved samples, the threshold is lowered dependent on the resonator quality by a factor of 2 until 10.

A further promising property of $Al_xGa_{1-x}As$ with indirect band gap is the only weak increase of the threshold for



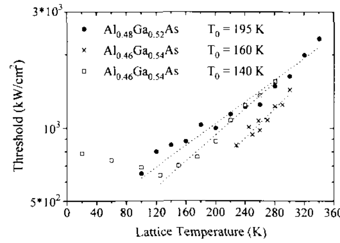
QMG2 Fig. 1. Laser emission at different pump intensities for a 90-μm-wide cleaved sample of $Al_{0.43}Ga_{0.57}As$ at 80 K. The resonator modes are sharp and well separated at this temperature.



QMG2 Fig. 2. Laser emission at different pump intensities for a cleaved sample $Al_{0.46}Ga_{0.54}As$ at 270 K still showing a clear modulation of the spectra.

laser emission with rising temperature. A comparison between the experimental data and a heuristic exponential dependence (see Fig. 3)[4,3] yields a constant T_0 = 195 K for a composition of $x = 0.48$. This property results in high stability of the laser activity, a relatively small threshold at room temperature, and a constant emission wavelength.

To investigate the microscopic origin of the stimulated emission we additionally performed gain measurements with the variable stripe-length method at low temperature (20 K) for uncleaved samples. The weaker transition probabilities for samples with larger aluminum concentration result in higher thresholds for



QMG2 Fig. 3. Threshold for laser emission as a function of lattice temperature for three samples with two different aluminum concentrations. The dotted lines are fits with $I_0 * \exp(T/T_0)$ yielding the constant T_0, which describes the threshold behavior.

stimulated emission and therefore in higher carrier densities, which broaden the gain spectrum and increase the renormalization effect. The carrier densities and temperatures can be extracted from lineshape fits using a model that includes self-consistently the renormalization of three conduction bands. Absolute values of the maximum gain are 200–250 cm^{-1}.

Our results seem to be very promising because laser activity is achieved with a very simple kind of resonator. Improvements in the laser performance should be achievable in an easy way by high-reflectivity coating of the resonator and optimized index guiding of the optical wave.

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QMG3 1445

A stable, high-power broadband Pr^{3+}-doped fiber superfluorescence source

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Broadband superfluorescence sources are required for high-grade fiber-optic gyroscopes, signal-processing fiber systems, atomic physics, and fiber sensors. Nd^{3+}- and Er^{3+}-doped fiber superfluorescence sources[1,2] have been demonstrated. We report the results of a Pr^{3+}-doped silica fiber superfluorescent source at 1049 nm. The mean-wavelength versus pump power and pump wavelength is investigated.

By using both single-pass and double-pass experimental configurations,[2] the doped fiber superfluorescent source is investigated with a 592 nm dye laser pump. The output power and linewidth versus absorbed pump power for the double-pass configuration are shown in

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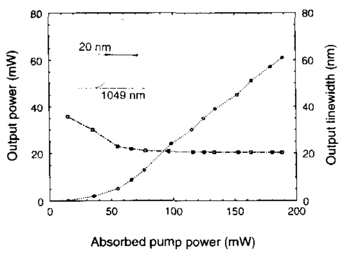
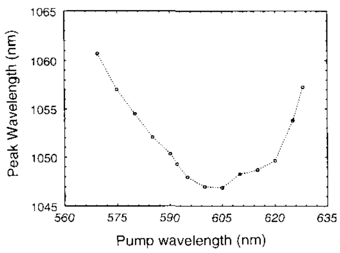


QMG3 Fig. 1. The output power and linewidth of the double-pass configuration versus the absorbed pump power. The inset is one of the typical output spectra.

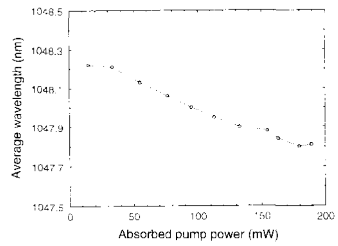


QMG3 Fig. 2. The peak wavelength of the superfluorescence emission versus pump wavelength for the double-pass configuration.

Fig. 1. With increasing of pump power, the linewidth narrows sharply from ≈35 nm to ≈21 nm reaching saturation regime. The output power has a straight line-fit slope efficiency of 40%. One of the typical output spectra is shown as inset of Fig. 1. It has a smooth Gaussian-like structure. A maximum output power of ≈61 mW is achieved.

The peak superfluorescent wavelength versus pump wavelength at a same absorbed pump power is shown in Fig. 2. The large variation of the peak wavelength is caused by site-to-site variations in the ionic environment of the glass matrix, giving rise to different positions of Pr-energy levels (inhomogeneous broadening). Increasing the pump wavelength from 570 nm to 600 nm, the peak is shifted to shorter wavelength, in contrast to the normal behavior, where increasing pump wavelength results in an increasing in emission wavelength. This is attributed to the two different matrix sites of the doped fiber[3] broadening differently. So the large inhomogeneous broadening linewidth and the two host matrix sites in the Alco-doped silica fiber demonstrate the broad variation of peak superfluorescent wavelength.

The intensity-weighted mean wavelength is one of the important parameters of the broadband source. The mean wavelength versus the absorbed pump power is shown in Fig. 3. It only has a small variation of 0.4 nm and a negative slope with increasing of pump power. This advantageous property stems from



QMG3 Fig. 3. The intensity-weighted mean wavelength versus pump power.

the weak unsymmetric fluorescence gain spectrum of the Pr^{3+}-doped fiber. For a doped fiber with a strong unsymmetric fluorescence spectrum, the gain at emission peak and dominant emission side exceeds gain of the weak fluorescence side. With increasing of pump power, the mean wavelength will shift significantly to the stronger emission wavelength side. This impairs output spectral stability with respect to output power. For the Pr^{3+}-doped silica fiber, the mean wavelength shifts to shorter wavelength because the increasing of pump power is as small as 0.4 nm. This wavelength shift should be reduced in the saturation regime.

A stable, single-mode-broadband Pr^{3+}-doped fiber superfluorescence source is demonstrated with a high output power of 61 mW and linewidth of 20 nm. Good output spectral stability is achieved.

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QMG4 1500

The short pulse duration limit for KrF laser systems

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The short pulse duration limit in high-power laser systems employing chirped pulse amplification is set by the limitations on width and shape and relative phase across the output spectrum. It is possible to improve the criteria for assessing the spectrum by looking at the relationship between a spectral distribution and its Fourier transform. This shows that the pulse duration at FWHM is more closely related to the spectral width in the wings of the spectrum, at perhaps the 5% level, than to the FWHM. Conversely, the shape of the spectrum is reflected more in the wings of the pulse and is important in the assessment of pulse contrast ratio.

The pulse duration achievable with any laser system is determined by a number of factors including the input spectrum, the amplifier gain spectral profile, any spectrally sensitive components, and the gain and saturation levels. Methods of optimizing the system include spectral filtering[1] and spatial dispersion.[2] The addition of passive spectral filtering can only lead to a modest reduction in pulse duration of perhaps 30%. However, it can also control the pulse shape and give, for example, pulses with a shorter rise time, and this may be useful for some applications.

In a heavily saturated amplifier such as KrF, the shortest pulses should be achievable using spatial dispersion in the amplifier. However, this may not be a practical solution for many large systems.

KrF lasers have been shown to demonstrate an apparent absorption feature close to the center of the spectral gain line.[3] This anomaly can increase the minimum pulse duration achievable with a KrF laser to more than 250 fs.[4] An experimental study has been carried out to learn more about this anomaly so as to assess the fundamental pulse duration limit and to enable proper optimization of the system to achieve this limit. Pulses as short as 70 fs have been obtained where additional benefit has been derived from the saturation of a chirped pulse to maintain the maximum spectral width.

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QMG5 1515

Generation of ultrashort x-ray pulses with high-contrast ultrahigh-intensity fs-lasers

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We review terawatt solid-state lasers based on chirped pulse amplification and their important parameters for high-intensity laser plasma interaction experiments. Interaction experiments have been performed with our 400 fs multiterawatt Nd:glass laser. High-efficiency second harmonic generation of pulses with intensities up to 500 GW/cm^2 enabled us to generate intensities up to 4×10^{18} W/cm^2 at λ = 527 nm. These pulses were focused on low and high z-material targets. Time resolved keV spectroscopy shows that short, several ps long x-ray bursts are generated when high-contrast fs-laser radiation is used to heat the plasma. Electron densities up to 3×10^{23} cm^{-3} are produced. Conversion efficiencies in the 4 Å–8 Å show that fs-laser-generated picosecond x-ray pulses give enough flux for future applications. Directions are dis-

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